SYNTHESIS AND MULTIFUNCTIONAL PROPERTIES OF POLYMER CAPPED LANTHANIDE DOPED BIMETAL OXIDE NANOCOMPOSITES

SYNOPSIS

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1. Introduction

1.1. Nanotechnology

Nanotechnology refers to a technological development that deals with the manipulation of matter at the nanoscale (Nasrollahzadeh et al,. 2019). In 1959, an American physicist Richard Feynman explained in American physical society meeting that the different method was possible by which individual atoms or molecules transform from one form to another smaller form using various sets of tools and he is known as the "Father of Nanotechnology" (Sharma et al,. 2019). Nanotechnology is the ability to control, understand and restructure the matter at atomic and molecular levels in the dimensions between 1 and 100 nm where distinct properties and exclusive phenomena allow numerous and novel applications in the real world (Hulla et al,. 2015; Roco, 2011). The matter shows different properties at nanoscale than at bulk or large scale. As the size of matter goes on decreasing from bulk scale, the properties may vary slightly. But when the size of matter drops below 100 nm, drastic changes in properties can take place (Bhushan, 2017). The peculiar physical and chemical properties of nanomaterials make them suitable for various applications such as medicine, optoelectronic devices, energy storage devices, sensors, etc (Patil and Burungale, 2020).

1.2. Nanoparticles

Nanoparticles are the fundamental building blocks of nanotechnology (Khan et al,. 2022). Nanoparticles are the solid particles engineered at atomic and molecular scale having size in the range of 1-100 nm. These nanosized particles display novel properties that are not shown by bulk material (Sharma et al,. 2019a; Wiesenthal et al,. 2011). Nanoparticles are mainly classified into three categories: Organic, Inorganic and Carbon-based nanoparticles. Organic nanoparticles include biodegradable, non-toxic nanoparticles like dendrimers, micelles, liposomes, ferritin etc. Inorganic nanoparticles are metal and metal-oxide based nanoparticles. Carbon based nanoparticles are completely made of carbon like fullerenes, graphene, carbon nanotube, carbon black etc. Nanoparticles are synthesised broadly by two methods: Bottom-Up and Top-Down method. Bottom-up method is the build-up of material from atoms to clusters to nanoparticles. Sol-gel, co-precipitation, hydrothermal, chemical vapour deposition are most common bottom-up method used for nanoparticles production. Top-down method is reduction of bulk material into nanometric scale particles. Mechanical milling, nanolithography, laser ablation and thermal decomposition are most widely used methods to synthesis nanoparticles (Anu Mary Ealia and Saravanakumar, 2017). The oxides of two different metals can affect the physical and chemical properties by synergistic interactions. Bimetal oxide nanoparticles modify and enhance structural properties, thermal stabilities and photocatalytic activities.

1.3. Bimetal Oxide Nanoparticles

Bimetallic nanoparticles are composed of two different metals in nano-meter range and have drawn greater attention than those of monometallic nanoparticles. Bimetal oxide nanoparticles are nanosized particles that contain oxides of two different metals either in composite form (e.g. CuO-ZnO, NiO-Co_3O_4) or mixed form (e.g. $NiFe_2O_4$, $CoMn_2O_4$) at the nanoscale which offer synergistic properties (Loza et al,. 2020; Sharma et al,.

2019). Copper (Cu) is a chemical transition element having atomic number 29 and electronic configuration is $[Ar]3d^{10}4s^{1}$. It is soft, malleable, ductile metal with very high thermal and electrical conductivity. Copper forms various compounds, usually with oxidation states +1 and +2, which are called cuprous and cupric respectively (Holleman et al., 2001). CuO has +2 oxidation state of Cu, while Cu_2O has +1 oxidation state. CuO has monoclinic crystal structure and is black in colour. Zinc (Zn) is a chemical element having atomic number 30 and electronic configuration is $[Ar]3d^{10}4s^{2}$. It is slightly brittle metal at room temperature. It exhibits only one normal oxidation state +2. Zinc burns in air with a bright bluish-green flame, giving fumes of ZnO (Holleman et al., 1985). ZnO has hexagonal Wurtzite crystal structure. Magnesium (Mg) is a Group 2 (alkaline earth) element within the periodic table and has atomic number 12 with electronic configuration $[Ne]3s^{2}$. Mg has only one normal oxidation state +2 (Jahnen-Dechent and Ketteler, 2012). Iron (Fe) is a Group 8 transition metal with atomic number 26 and electronic configuration $[Ar]3d^{6}4s^{2}$. Common oxidation states of iron are +2 (ferrous) and +3 (ferric). Fe^{2+} compounds are generally green or light-coloured and can be easily oxidised to Fe^{3+}. FeO, $FeCl_3$ and $FeSO_4$ are the compounds of iron having oxidation state +2. Fe^{3+} compounds are typically reddish-brown or yellowish in colour. Common example of iron compounds with oxidation state +3 are Fe_2O_3, $FeCl_3$ and $Fe_2(SO_4)_3$. Manganese (Mn) is a transition element having atomic number 25 and electronic configuration $[Ar]3d^{5}4s^{2}$. Common oxidation states of Mn are +2, +3, +4, +6, +7. A particularly common oxidation state for manganese in aqueous solution is +2, which has a pale pink colour. Manganese forms many compounds like $MnCl_2$, Mn_2O_3, MnO_2, Mn_3O_4. (Rayner-Canham and Overton, 2003). Mn_3O_4 is a mixed oxide with two oxidation states of manganese. Two Mn atoms are in Mn^{3+} state and one atom is in Mn^{2+} oxidation state. Mn_3O_4 has tetragonal crystal system and is brownish-black in colour. The capping of Polymers like PVP to bimetal oxide nanoparticles help to control the size, shape and prevents agglomeration of nanoparticles.

1.4. Polyvinylpyrrolidone (PVP)

The PVP polymer is mostly used in nanoparticle synthesis and it is a bulky, non-toxic, non-ionic polymer with C=O, C-N and CH_2 functional group. The PVP is made of from polymerisation of monomer vinylpyrrolidone using hydrogen peroxides as initiator. The PVP molecule contains a strongly hydrophilic (pyrrolidone) component and a hydrophobic portion (the alkyl group). PVP, a water-soluble polymer, is great stabilizer and reducing agent which prevents aggregation of nanoparticles via the repulsive forces that arise from its hydrophobic carbon chains extends into solvents and interact with each other. PVP can serve as a surface stabilizer, growth modifier, nanoparticle dispersant and reducing agent depending on particular synthetic conditions and material system (Amri and Roger, 2020; Koczkur et al., 2015). PVP is an amorphous colourless polymer that allows faster ionic mobility than other semi-crystalline polymer (Mohammed et al., 2018). The polymer capped bimetal oxide nanoparticles lead to nanocomposites with hybrid properties.

1.5. Nanocomposites

Nanocomposites are the solid materials which are composed from various phases where one of the phases has one, two or three dimensions of less than 100 nm in size (Omanović-Mikličanin et al., 2020).Nanocomposites are mixture of two or more materials producing a new material with at least one dimension in nano range. The constituent materials are mixed in such a way that the resulting material exhibits the averaged properties between the two. The mixing of the two materials is done because they show better properties such as catalytic properties, thermal stability and adsorption properties, etc. than individual materials (Sharma et al., 2019b). Nanocomposites consist of two words: Nano + Composites. Composites are combination of two or more chemically distinctive materials in which at least one phase of materials has dimensions in nanoscale range i.e. less than 100 nm. Nanocomposites have unique physical, chemical, optical, mechanical, magnetic and electrical properties and, thus, have wide range of application that can benefits society (Singh and Agarwal, 2016). The properties of PVP capped bimetal oxide nanocomposites can further be tunned by doping of lanthanides. The lanthanide doping broadens the application potential of these nanocomposite due to unique 4f-electron configuration.

1.6. Lanthanides Doping

Lanthanides refer to group of 15 almost chemically similar elements from Lanthanum (La) to Lutetium (Lu) which are associated with the filling of 4f shell. Nanoscale manipulation of lanthanide-doped nanoparticles can lead to important modification in their optical properties. The study of lanthanide-doped nanoparticle is a new interdisciplinary field that combines chemistry and physics principles with photochemistry, biophysics, solid state physics and material science (Wen and Wang, 2014). Several variations were depicted in structural, optical and electrical characteristics of nanomaterials when lanthanum is doped on it (Aslam et al., 2021a). The optical gap decreased when the content of lanthanide Gd^{3+} doping with Mg-Al nanocomposites is increased. It was possible to obtain a very promising material for optoelectronic devices like LASERs, LEDs, Solar cells and other industrial applications (Shehata et al,. 2021a). The lanthanide-doped up-conversion nanoparticles which can absorb two or more low-energy photons and radiate high-energy photon are favoured by many researchers in various fields. The 4f electrons of rare-earth ions constitute the rich metastable energy levels, which makes the up-conversion process of lanthanide doped nanocrystals diversified (Du et al,. 2022).

2. Literature Review

(Htwe, 2020) analysed structural, morphological, compositional properties, optical properties and energy band gap of ZnO nanoparticle synthesized using zinc acetate dehydrate and NaOH using precipitation method. The synthesized nanoparticles analyse using XRD and SEM, and UV- Vis Spectroscopy. Synthesized nanoparticles can be utilized as building materials in fabrication of various personal care products and optoelectronic devices including solar cells, LED’s etc.

(Aslam et al,. 2021b) synthesized lanthanum doped-cobalt ferrites having chemical formula $CoLa_xFe_{2-x}O_4$ with composition x = (0.00, 0.0.15, 0.045, 0.060) by chemical co-precipitation method. The prepared samples were characterized by XRD, FTIR, Raman spectroscopy, and current-voltage(I-V) technique. The structure of the crystal was analysed by XRD. The crystallite size of nanoparticles was examined in the range of 21-25 nm, and a fluctuating trend was found with the inclusion of La^{3+} cations. The XRD patterns verify the contraction of lattice constant and unit cell volume with the substitution of La^{3+} cations except for the concentration of x = 0.060. The resistivity of all samples was calculated by the application of two probes I-V technique. The maximum resistivity of the order of 81.129×10^5 Ω cm was found for the concentration of x = 0.060 at 723 K which makes it useful for high-frequency gimmicks applications.

(Shehata et al,. 2021b) synthesized un-doped MgO-$MgAl_2O_4$ and Gd^{3+} -doped MgO-$MgAl_2O_4$ nanocomposites via co-precipitation method. The effects of Gd^{3+} contents on the structural and optical properties of Mgo-$MgAl_2O_4$ nanocomposites were investigated using SEM, high-resolution TEM, XRD, FTIR and UV-Vis spectroscopies. High-resolution TEM shows that Mgo-$MgAl_2O_4$ powder are uniform spherical shape nanoparticles. The XRD shows that the nanocomposites consist of face-centred cubic $MgAl_2O_4$ and MgO crystal structures. The average crystallite sizes of Mgo-$MgAl_2O_4$ nanocomposites are in the range of 8-40 nm. The quantitative elemental analysis the EDX illustrates that the nanocomposites samples are nearly stoichiometric Mgo-$MgAl_2O_4$ 48 to 52%, respectively. SEM was used to study the surface morphology of Mgo-$MgAl_2O_4$ nanocomposites that reveals the existence of both the individual nanoparticles and their aggregates. The optical bandgap was decreased with the presence of Gd^{3+} from 4.85 to 3.66 eV for 0.0 and 3% of Gd^{3+} content, respectively.

(Abraham et al,. 2018) reported a low cost, single step preparation method for the synthesis of CuO-ZnO nanocomposite through simple co-precipitation technique. XRD studies show that the composite contains only hexagonal wurtzite ZnO and monoclinic CuO structures. The magnetic studies of CuO-ZnO heterostructures were also conducted in order to elucidate the source of the ferromagnetism observed at room temperature. The catalytic efficiency of the prepared nanocomposite was estimated by the degradation of methylene blue and eosin yellowish which also shows its suitability as a promising candidate in waste water treatment.

Alam et al. (2013) prepared polyaniline/ZnO nanocomposite with diameter 40-50 nm successfully fabricated by coprecipitation method of ZnO via in situ polymerization of Polyaniline (Pani). XRD, HRTEM, FTIR, UV-Vis absorption spectra, TGA and electrical properties were studied. HTTEM studies showed that the prepared ZnO nanoparticles were uniformly dispersed and highly stabilized throughout nanocomposite were studied to investigate the optical behaviour after doping the ZnO nanoparticle into the polymer matrix. The inclusion of ZnO nanoparticle gives rise to the red shift of π-π^* transition of Pani. The nanocomposite was found to be thermally stable upto 130° C and showed conductivity value of 3.0×10^{-2} Scm^{-1}.

(De Souza et al., 2018) studied a hybrid nanocomposite based on a polymer matrix constituted of Polyaniline Emeraldine-salt form (PANI-ES) reinforced by CuO particles obtained by in situ polymerization. Structural, morphological and electrical properties of the pure materials and nanocomposite form were investigated. The presence of CuO particles in the nanocomposite material affected the natural alignment of the polymer chains. XRD technique allowed the visualization of the polymer amorphization in the nanocomposite form, suggesting an interaction between both phases. The FTIR spectra confirmed this molecular interaction due to the blue shift of the characteristic absorption peaks of PANI-ES in nanocomposite form. SEM images revealed that the polymer nanofiber morphology was no longer observed in the nanocomposite. The CuO spherical particles are randomly dispersed in the polymer matrix. The density functional theory plus the Coulomb interaction method revealed a charge transfer from PANI to CuO slab. Moreover, the density of states (DOS) has revealed that the nanocomposite behaves as a metal. In agreement, the electrical conductivity showed an increase of 60% in the nanocomposite material.

(Sankar et al,. 2020) focused on the synthesis of polypyrrole (PPy) wrapped nano copper-alumina (Cu-Al_2O_3) composite by an in-situ polymerization of pyrrole in the presence of Cu-Al_2O_3 nanoparticles. The polymerized samples were characterized by FTIR, XRD analysis, DSC, and TGA. The properties such as AC and DC conductivity, dielectric constant, and ammonia gas sensing performance of PPy/Cu-Al_2O_3 composites were investigated in detail as a function of Cu-Al_2O_3 content. The FTIR spectra showed the existence of sharp and resolved infrared bands of nanoparticles in the PPy chain. The presence of the crystalline peaks of Cu-Al_2O_3 in the PPy matrix was confirmed from the XRD analysis. SEM images revealed the homogenous growth of Cu-Al_2O_3 in the polymer with the formation of spherically shaped particles. The HR-TEM observations showed that Cu-Al_2O_3 particles were dispersed at a nano-meter level in the nanocomposites with a width of 30-60 nm. The glass transition temperature of composites obtained from DSC was found to be increased with increase in the content of nanoparticles. TGA analysis proved that the nano Cu-Al_2O_3 in the content in the composites acted as a mass transport barrier that retards the degradation of the product. The AC conductivity and dielectric constant of the nanocomposite showed that the maximum electrical properties were observed for the composite with 5 wt% loading of Cu-Al_2O_3. DC conductivity showed that the PPy/Cu-Al_2O_3 composites have higher electrical conductivity than PPy. Therefore, the improved properties of synthesized PPy/Cu-Al_2O_3 nanocomposite can be useful for developing functional composite material for the fabrication of sensors, electronic devices, and high energy storage capacitors.

(Velliyan and Rajendran, 2021) synthesized CuO and Cerium doped CuO nanoparticles via combustion technique. The samples were studied for their structural, vibrational, morphological and optical properties using XRD, Raman spectroscopy, Field emission scanning electron microscopy (FESEM) and Diffuse reflectance studies (UV-DRS) techniques, respectively. XRD studies revealed that, on increasing doping concentration the diffraction peak becomes broader and the particle size changes from 22 nm to 15 nm. The change in morphology of the sample from spherical to dumbbell shape with increased doping concentration

have been found from FESEM studies. The obtained optical band E_g was found to be increasing from 1.2eV to 1.3eV with increasing concentration of dopant.

(Donkova et al,. 2011) synthesized Au/ZnO nanocomposites of different gold contents (0.8, 2.5 and 9%) and specific surface areas (from 41 to 51 m^2/g) via a coprecipitation method. The pure ZnO was obtained at the same experimental conditions. The samples were characterized by XRD, SEM, TEM, HRTEM, and XPS. The influence of gold nanoparticles (Au-NPs) loading on the catalytic activity of Au/ZnO nanocomposite was studied in the model reaction of CO oxidation. Spherical shape and homogeneous distribution of Au-NPs were observed in all samples prepared. The average size of Au-NPs in the obtained catalysts are almost the same (about 4 nm) allowing the studied effect to be manifested. The decrease of intrinsic catalytic activity of the coprecipitated Au/ZnO nanocomposites followed the sequence 2.5, 9, and 0.8% Au, as corresponding to the decrease of relative surface content of Au-NPs.

(Jan et al,. 2014) synthesized CuO nanostructures doped with Ce at different concentration levels via co-precipitation method. The prepared samples have been characterised by XRD, SEM, FTIR, UV-Vis absorption spectroscopy. Structural studies show the presence of a monoclinic structure of CuO for undoped and Ce doped samples without any additional impurity phases. SEM images have revealed the rod-like morphology with an average diameter of 30 nm for undoped CuO. FTIR results of undoped and Ce doped CuO nanostructures have further confirmed the formation of monoclinic CuO. The optical band gap calculated from the Tauc relation has been observed to be 2.48 eV for undoped CuO nanostructures, which is found to decrease down to 2.2 eV with the increase in the Ce doping level. This tuning in the optical band gap may be attributed to the merging of the impurity band with the conduction band of CuO. The Ce doping induced effects on the antibacterial activity of the CuO nanostructures have been examined by recording the growth curves of bacteria in the presence of prepared nanostructures. It has been observed that S. aureus bacterium may be completely eradicated by the application of Ce doped CuO nanostructures. The cytotoxicity analysis has shown that the synthesized undoped and Ce doped CuO nanostructures are biocompatible and non-toxic towards the human cell line SH-SY5Y cells.

(Ramesan et al., 2017) prepared poly(vinyl cinnamate)/zinc oxide (PVCin/ZnO) by in situ polymerization method using different mass percentages of ZnO nanoparticles. The formation of nanoparticles in the composites was analysed by TEM, FESEM, XRD, DSC and TG measurements. The TEM and SEM images showed the uniform dispersion of nanoparticles within PVCin matrix. The results of XRD indicated that the metal oxide particles had entered into macro-molecular chain in PVCin. The glass transition temperature of the composites was shifted towards higher temperature with the increase in concentration of ZnO nanoparticles. Thermal stability studies showed a remarkable increase in thermal resistance of composites, and the thermal stability increases with an increase in concentration of metal oxide particles. The AC electrical conductivity of prepared composite has been investigated at different temperature at various frequencies. The electrical conductivity was found to be increased with increasing temperature.

(Fathy and El-Kady, 2013) has studied Copper-alumina composites prepared by powder metallurgy (P/M) technology. Nano-Cu/Al_2O_3 powders, was deoxidized from CuO/Al_2O_3 powders which synthesized by thermochemical technique by addition of Cu powder to an aqueous solution of aluminium nitrate. The Al_2O_3 content was added by 2.5, 7.5 and 12.5 wt% to the Cu matrix to detect its effect on thermal conductivity and thermal expansion behaviour of the resultant Cu/ Al_2O_3 nanocomposites. The result showed that alumina nanoparticles (30 nm) were distributed in the copper matrix in a homogeneous manner. The measured thermal conductivity for the Cu-Al_2O_3 nanocomposites decreased from 384 to 78.1 W/mK with increasing Al_2O_3 content from 0 to 12.5%.

(Blessy Pricilla et al., 2021) have studied that semiconductor materials are widely explored for their potential as photocatalysts in the remediation of toxic organic waste, with metal oxides playing a key role in the photodegradation of dye pollutants. In this work, a CuO-MgO nanocomposite was synthesized using chemical co-precipitation approach. The resulting material was analysed for its structural, morphological, and optical features using XRD, SEM, and UV–Vis spectroscopy. The XRD pattern confirmed the composite nature of CuO–MgO, while SEM images displayed a homogeneous distribution of spherical particles. EDAX analysis was performed to determine the elemental composition, and HRTEM further verified the spherical morphology and composite structure. The optical band gap was found to be 1.67 eV. The photocatalytic capability of the composite was tested against Methylene Blue dye, showing a degradation efficiency of 87% after 60 minutes of exposure.

3. Research Gap Identification

In fact, many researchers have studied synthesis of polymer mediated metal oxide nanoparticles and polymer mediated metal oxide nanoparticles doped by different transition elements but there is very less literature on the synthesis of polymer capped lanthanide doped bimetal oxide nanocomposites. The present study will discuss the comparative chemical synthesis, characterization and applications of polymer capped bimetal oxide nanocomposites and polymer capped lanthanide doped bimetal oxide nanocomposites. In addition to this, synthesized nanocomposites will be used for the photocatalytic and antioxidant activity.

4. Objectives

In the light of above discussions, the objectives of present study are as follows:

- To study chemical synthesis of polymer capped lanthanide doped bimetal oxide nanocomposites.
- To characterize the synthesized nanocomposites by using different characterization techniques.
- To study the thermal and electrical properties of synthesized nanocomposites.
- To explore the photocatalytic and antioxidant applications of synthesized nanocomposites.

5. Proposed Methodology

5.1. Materials

Copper (II) nitrate trihydrate (≥ 99%, Emplura), Magnesium Nitrate hexahydrate (99%, Qualigens), Zinc nitrate hexahydrate (≥96%, Emplura), Iron (III) Nitrate nonahydrate (≥ 98.1, Merck), Manganese (II) nitrate tetrahydrate (98%, Alfa aeser), Sodium hydroxide (≥97%, Emplura), Polyvinylpyrrolidone (PVP-1,300,000), different lanthanides for doping and distilled water are the chemical used in this work.

5.2. Synthesis of polymer capped lanthanide doped bimetal oxide nanocomposites

The synthesis of polymer capped bimetal oxide nanocomposites will involve the co-precipitation method. Initially, we will utilize particular precursors of bimetal materials which will be dissolved in fixed amount of distilled water and will be stirred on magnetic stirrer for certain time period. For, lanthanides doping in polymer capped bimetal oxide nanocomposites, different concentrations of lanthanide elements will be dissolved on above precursor solution of bimetal solution. A fixed volume of polymer PVP will be dissolved in above bimetal precursors solution and will be stirred for specific time interval. Then, a fixed molar concentration of NaOH will be added dropwise for maintaining the pH of above solution at certain value. Further, the prepared nanocomposites will be centrifuged as well as washed with distilled water and ethanol for 3 times and then will be dried in vacuum oven at particular temperature and time. Finally, these nanocomposites will be utilized for multifunctional characterization and various applications.

5.3. Characterization of synthesized bimetal oxide nanocomposites

The synthesized polymer capped bimetal oxide nanocomposites will be characterized to determine its various physical as well as chemical properties such as crystallite size, inter planar spacing, crystal structure, bandgap, functional groups, surface morphology, particle size, electrical and also thermal properties. The characterization techniques will be used for determining these parameters are X-ray diffraction (XRD), UV-Visible spectroscopy, Fourier transform infrared spectroscopy (FTIR), Scanning electron Microscope (SEM), Energy dispersive X-ray spectroscopy (EDS), Transmission electron microscope (TEM), Thermogravimetric analysis (TGA) and Differential Scanning Calorimetry (DSC).

5.4. Photocatalytic activity

In this study, experiments will be performed to evaluate the photocatalytic properties of synthesized polymer capped bimetal oxide nanocomposites by photocatalytic degradation of commercial dyes. The photocatalytic decomposition of dyes will be examined by measuring the absorbance at regular time intervals by using UV-Visible spectrophotometer.

5.5. Antioxidant activity

The antioxidant activity of synthesized polymer capped bimetal oxide nanocomposites will be examined by investigating the radical scavenging ability against 2,2-dipenyl-1-phenylhydrazyl (DPPH) free radical at different concentration. The absorbance of solutions will be measured by UV-Visible spectrophotometer.

6. Thesis Outline

The thesis will be comprised of following chapters:

Chapter 1 (Introduction): It will constitute the brief account about nanotechnology, nanoparticles, bimetallic nanoparticles, polymer PVP, nanocomposites and applications of polymer capped nanocomposites. It will also include the objectives of proposed study.

Chapter 2 (Literature Review): This chapter will deal with intense literature with context to the synthesis, characterization and applications of polymer mediated nanocomposites. It will also include the research gap identification.

Chapter 3 (Materials and Methods): This chapter will comprise the detail of materials, chemical synthesis, characterization techniques and application of polymer capped bimetal oxide nanocomposites.

Chapter 4 (Results and Discussion): This chapter will include the reports regarding comprehensive characterization and applications of synthesized polymer capped bimetal oxide nanocomposites and comparison of the findings the work.

Chapter 5 (Summary and Conclusion): It will include the overall summary and conclusion of the entire study with regard to the work context to the objectives cited.

Chapter 6 (References): This will include references which will be strictly according to the Harvard style.

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CERTIFICATE

(SYNOPSIS APPROVAL CERTIFICATE)

This is to certify that the Synopsis/Revised Synopsis for Ph.D. Thesis titled, **" SYNTHESIS AND MULTIFUNCTIONAL PROPERTIES OF POLYMER CAPPED LANTHANIDE DOPED BIMETAL OXIDE NANOCOMPOSITES ",** submitted by Mr. Chuni Lal to the Career Point University, Hamirpur (H.P.), India in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in the Division/Department of Physics, School of Basic & Applied Sciences has been approved by the Research Advisory Committee (RAC) after an Oral Examination of the student on dated 26.06.2024.

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